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DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

ALBERT F. WOODS, CHIEF.

THE WILT DISEASE OF COTTON AND ITS CONTROL.

BY

W. A. ORTON,

ASSOCIATE PATHOLOGIST.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Physiology and Pathology,
Washington, D. C., October 30, 1900.

Sir: I respectfully transmit herewith a report by Mr. W. A. Orton, of this Division, describing briefly the progress made in the study of the Wilt Disease of Cotton, also known as "Frenching" and "Blight." This disease has for several years done serious injury in many parts of the cotton belt. The areas affected by it are annually increasing in size, and each year brings to the Department reports of outbreaks in localities hitherto supposed to be free from the malady. It is at present a serious menace to the cotton industry. The parasitic nature and life history of the fungus causing the disease have been thoroughly discussed in a former report by Dr. Erwin F. Smith, of this Division. The work of the Department on this disease is still in progress, but it is thought best to present a brief outline of the more important results obtained up to this time. It has been found that certain races are resistant to the malady, and results obtained in the experiments and by certain growers cooperating with the Department indicate that resistant strains can be obtained quite readily by selection. All other methods of fighting the disease have so far proved ineffective. Every effort will therefore be put forth to improve and develop these resistant strains.

I respectfully recommend that this report be published as Bulletin No. 27 of this Division.

Respectfully,

Albert F. Woods,
Chief of Division.

Hon. James Wilson,
Secretary of Agriculture.

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WILT DISEASE OF COTTON AND ITS CONTROL.

DISTRIBUTION.

The wilt disease is now known to occur on the coast of South Carolina, where it attacks the fine sea island cotton, and at Dillon, Salters, and other places in the same State, where it attacks upland cotton.

Prof. F. S. Earle, of the State experiment station, reports it to be widely distributed in Alabama, particularly in the southern part, and states that it is undoubtedly growing worse from year to year. It has been reported from many localities in Georgia, and is known to occur in Florida and Arkansas.

It is certain that this disease is widely distributed through the Southern States, and it is probable that it occurs in many places where it has not yet been distinguished from other troubles, such as "rust" and the effects of lightning.

EXTENT OF LOSS.

The annual loss from the wilt disease is very considerable. It is more keenly felt by the individual planters than most cotton troubles, because the disease remains in the soil and grows worse with each succeeding crop. On the sea islands of South Carolina alone a careful estimate indicates that nearly, if not quite, one-third of the land planted to high-grade cotton is affected by this disease, the larger portion of it so badly that it is no longer profitable to plant it in cotton. In many instances it has been necessary to abandon from 20 to 50 acres on a single plantation. Much of this land is tile-drained and in a high state of cultivation. No other crop has been so profitable as the sea island cotton, and the problem before these planters is a very serious one. The loss to the planters of upland cotton in areas affected by the disease has been proportionally great. On one farm in Dillon, S. C., where the Department has been conducting some experiments, 15 acres of fine land are already affected and the disease is spreading rapidly on this and adjoining plantations. The result of planting these infected soils with the ordinary varieties of cotton is shown in Plate I, in which fig. 1 shows a field of diseased cotton and fig. 2 a field of healthy cotton. The loss to this community from the wilt disease the past season is estimated at several thousand dollars. In Alabama the loss from this disease is reported from many sources to be very large.

The importance of the disease, however, does not lie so much in the amount of the present loss as in the danger of its future increase, for it must ultimately spread so much as to entail far greater losses and possibly threaten the life of the industry unless the methods for its control are perfected.

DESCRIPTION OF THE DISEASE.

The wilt is very distinct from any other disease of cotton, so that there need be no difficulty in its identification. It usually makes its first appearance in the spring about the last of May, when the plants are 6 to 8 inches high. It appears in well-defined areas, which enlarge if cotton is planted on the same land again. The first outward indication of its presence is a dwarfed growth and unhealthy appearance of the plants. The leaves turn yellow between the veins, their margins shrivel up, and some plants wilt and die at once. In other plants the progress of the disease is often slow, and many of them live the entire summer and die late in the season. On cutting across the stem of a diseased plant, the woody part will be found to be stained brown wherever the disease is present. In the absence of microscopic examinations, this brown discoloration of the internal tissue is the best ocular evidence of the presence of the wilt disease.

Plants may partially recover from a severe attack of the wilt disease by the development of strong lateral branches near the ground. Such plants may be distinguished by their dwarfed and bushy appearance and by the tendency of their branches to lie prostrate on the ground.

CAUSE OF THE DISEASE.

The cause of the wilt disease of cotton is a fungus, *Neocosmospora vasinfecta* (Atk.) Erw. Sm., which attacks the plant from the soil. It first enters the smaller roots and subsequently grows from these into the taproot and stem, filling the water ducts with its mycelium. The result is that the supply of food and moisture carried up from the roots is greatly decreased and the symptoms described above are produced. The nature of the fungus has been fully discussed in Bulletin No. 17 of this Division,[1] and it will not be necessary to enter into details here, but only to outline the subject and to record some additions to our knowledge.

The wilt disease of okra is believed to be caused by the same fungus which produces the cotton wilt. No inoculation experiments have been tried, but in the experience of the writer okra has never failed to contract the disease when planted in fields infected with the cotton-wilt disease.

[1] Smith, Erwin F. Wilt Disease of Cotton, Watermelon, and Cowpea. 1899.

Both the wilt disease of okra and that of cotton are sometimes complicated by the presence in the field of the root nematode, *Heterodera radicicola*. The combined attack of these two parasites results in somewhat greater injury to the plants than would be caused by either one alone. This is particularly true of okra, which suffers considerably more from the attacks of the nematodes than cotton growing beside it. It is not believed by the writer, however, that the assistance of the root nematodes or of any fungus is necessary to allow the wilt fungus to gain entrance to the roots of cotton. Some of the worst cases of wilt disease that have been observed were on land where no root nematodes could be found. Nor is it believed that mechanical injury to the roots from cultivation or other causes is necessary to produce infection. Cotton planted on infected fields late in the season, after cultivation had ceased, and when conditions were not favorable to the growth of damping-off fungi in the soil, contracted the disease at the usual time. The indications are that the fungus is a sufficiently aggressive parasite to make its way unaided into the vascular system of the plant whenever the plant is liable to infection.

The progress of the disease is always slow as compared with that of other plant diseases. The period of incubation, or the time elapsing after the young seedling is exposed to the attacks of the fungus and before the disease becomes manifest, is usually at least forty days and often much longer. Much depends on the individual plant itself. The conditions which favor the progress of the fungus through the plant are not fully understood, but from some observations that have been made it is believed that highly fertilized plants, growing vigorously, succumb more readily than those which have grown on poorer soil.

In the early history of the wilt disease the cause was supposed by the planters to be the excessive applications or injudicious use of commercial fertilizers, and many of the leading planters in the Sea Islands made careful experiments with various modifications of their fertilizers, such as the use of marl, salt mud, kainit, and lime, and the increase or decrease of the proportions of phosphoric acid and potash. Mr. W. G. Hinson, of James Island, South Carolina, a very successful planter, has informed the writer that the result of all these trials has been to convince those who made them that the disease can not be controlled by any changes in their system of fertilizing.

The wilt disease occurs in so many widely separated localities and under such varied cultural conditions that it is not probable that any errors in the agricultural practice are the primary cause of the trouble, although the planting of cotton year after year on the same land and the common practice of plowing under the last year's stems in preparing the ground in the spring both tend to hasten the spread of the wilt fungus after it has once been introduced.

NATURAL INFECTIONS.

The effect of repeated infections of the small roots of the cotton is very noticeable, especially when the plants are somewhat resistant to the disease. Small tufts of roots grow from each point of infection, doubtless on account of some stimulus exerted by the fungus. Several short roots will thus start from a place which would normally have produced one longer branch. (Pl. III, fig. 1.)

Many of these little roots are killed by the fungus and others grow in their places, so that the tufted appearance of the rootlets is more pronounced late in the season. The same result has been produced in the laboratory by inoculating seedling cotton plants with pure cultures of the cotton-wilt fungus. Similar root tufts are found associated with the wilt diseases of okra, cowpea, watermelon, and cabbage, and they are believed to be characteristic of this class of root diseases.

In the case of cotton their presence on the roots demonstrates the presence of the wilt fungus in the soil, even when the amount is so small that no harm is visible aside from the reduced growth of the plants. (Pl. III, fig. 2.) This dwarfing of the plants is due to the killing of the small roots and is often visible over a considerable area surrounding a badly infected spot. For this reason the loss in yield on such a field is much greater than would appear simply from a consideration of the badly diseased areas, as the dwarfing due to the injuring of the small roots considerably curtails the yield.

ARTIFICIAL INFECTIONS.

Since the publication of Bulletin No. 17, the wilt disease has been produced in healthy cotton plants by inoculating the soil in which they grew with pure cultures of conidial stages of *Neocosmospora vasinfecta*. This removes any doubt as to the causal relation of the fungus to the disease which might arise from the failure of the previous inoculation experiments. The plants were grown for a few weeks in pots, and then a small quantity of fungus from a pure culture was placed in the bottom of each one. Eight days later they were transplanted to the open ground. The first case appeared after about 35 days. Fourteen out of 24 plants contracted the disease. The fungus was abundant in the vascular bundles of 7 plants and they showed all the other symptoms of the disease. The other 7 infected plants were only slightly diseased, although the fungus was found in the vessels of the stem. The check plants, 25 in number, all remained healthy. It will be noted that the length of time between the inoculation of the soil and the appearance of the disease in this experiment (35 to 50 days) was practically the same as elapses in the field between the germination of the seed and the first appearance of the disease. That a larger proportion of the inoculations did not succeed is believed to be due to the small amount of

fungus used and to the natural resistance of the plants. The cotton plant inoculations described in Bulletin 17 were all made in the greenhouse and it is now believed that the negative results were due either to the slow growth of the plants or to the fact that they were naturally resistant.

THE FAILURE OF SOIL FUNGICIDES.

Careful experiments have been made with a large number of substances applied to the soil in the hope of killing the fungus, but all the results obtained up to the present time indicate that there is no hope of success from the use of any fungicides sprayed on the plants or applied to the soil.

Fields uniformly infected with the wilt disease were selected, and over twenty different substances were applied in amounts as large as it was thought safe to use. In many cases the expense of their application in such quantities was so great as to make their use impracticable had they proved efficacious. In other cases, as in the use of materials containing copper, continued applications in such large quantities would be likely to injure the soil.

The following were among the fungicides tried, nearly all of which were tested in duplicate or triplicate (in different localities):

1. *Bordeaux mixture*, 1,200 gallons per acre, applied to the soil ten days before planting.

2. *Bordeaux mixture*, 1,200 gallons per acre, applied to the soil before planting as above, and also sprayed on the plants and soil at intervals during the summer.

3. *Bordeaux mixture*, 1,200 gallons per acre, with the addition of a small quantity of molasses to increase the solubility of the copper.

4. *Bordeax mixture and sulphur*, prepared by adding to each barrel of a mixture containing the ordinary amounts of copper sulphate and lime 6 pounds of sulphur and 6 pounds of lime that had been boiled together one hour. This was mixed with the soil in the row ten days before planting.

5. *Bordeaux mixture*, 3,600 gallons per acre. This is equivalent to 546 pounds of copper sulphate per acre, but the cotton grew well here until attacked by the wilt disease. To all appearances neither the cotton nor the wilt fungus was affected by this very heavy application, which was on a rather small plot (250 square feet).

6. *Copper carbonate*, applied in solution to the soil just before planting, at the rate of 136 pounds per acre.

7. *Copper acetate*, applied in solution to the soil just before planting, at the rate of 102 pounds per acre.

8. *Lime* (fresh stone lime) was applied to infected land in September, 1899, at the rate of 3, 4, 5, and 6 tons per acre. The lime was harrowed in as soon as it had become slacked. An equal area was left untreated, and cotton was planted in the usual way in 1900. Lime was also applied to other infected fields in the spring, shortly before planting, at the rate of 2,000 and 4,000 pounds per acre.

9. *Sulphur* (flowers of sulphur) was applied to the soil before planting, at the rate of 400 and 600 pounds per acre.

10. *Lime-sulphur mixture*, consisting of 30 pounds of lime, 20 pounds of sulphur, and 60 gallons of water. The lime was slacked and boiled with the sulphur one hour. It was applied at the rate of 600 and 900 gallons per acre.

11. *Liver of sulphur*, applied in solution before planting, at the rate of 30 pounds per acre.

12. *Iron sulphate*, applied in solution before planting, at the rate of 100 pounds per acre.

13. *Carbolic acid*, applied at the rate of 12 and 18 gallons of crude acid per acre.

14. *Caustic soda*, applied in 8 per cent solution at the rate of 1,000 pounds of commercial caustic soda per acre.

15. *Formalin*, applied in 10 per cent solution at the rate of 100 pounds of the commercial (40 per cent) formalin per acre.

16. *Kainit*, used at the rate of 2,000 and 4,000 pounds per acre.

For the purpose of comparison, in all cases, untreated plots were left beside those subjected to the foregoing treatments. The wilt disease was very bad on these fields, and nearly all the cotton died on both the treated and the untreated plots, but no difference traceable to the fungicides used could be observed between them.

A test was also made of "Brown's Watermelon Wilt Remedy", which has been put on the market as a preventive for both the cotton and the watermelon diseases. This treatment consisted in soaking the seed twenty-four hours in a patent compound,[1] with the addition of a small amount of air-slacked lime to the soil before planting. It was given a careful trial, according to the directions of the maker, but no difference was observed between the treated plots and the untreated plots beside them.

At the request of the Department, the same remedy was tested on watermelons by Mr. T. S. Williams, of Monetta, S. C., a well-known grower of melons, who has had much experience with the watermelon wilt disease. The seed for 200 hills was treated according to directions, and 200 other hills beside them were left untreated. A perfect stand was obtained, and the plants were thinned out to one in a hill. A careful count sixty-five days after planting showed 195 of the 200 treated plants killed by the wilt disease. In the other (untreated) row 187 of the plants were killed by the fungus.

PREVENTIVE MEASURES.

HYGIENIC TREATMENT.

In the cotton wilt, as in many other plant diseases, certain preventive or palliative measures, based on our knowledge of the way the disease spreads, are very important. These are as follows:

(1) *Rotation of crops.*—Land once infected with this disease has never been freed from it. It is important, therefore, that such land should not be planted for several years to okra or any variety of cotton subject to this disease. The length of time the fungus will live in the soil is not yet determined, but four years' rest has proved insufficient in several cases. Other crops—as corn, cowpeas, cabbage, watermelon, etc.—may, it is believed, be planted on this land with safety.

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[1] Stated by the Division of Chemistry, to which samples were submitted, to be made of a mixture of liver of sulphur and lime.

The greatest spread of the wilt disease is by the direct growth of the fungus through the soil from diseased to healthy areas. On this account an area considerably larger than that on which the plants are wilting should be included in this rotation.

(2) *Removal of diseased plants.*—Another important source of infection is the diseased plants themselves. The fungus produces on the dead stems and roots great numbers of spores, which are carried to other places in a variety of ways. All diseased plants should be pulled and burned as soon as discovered, so as to prevent the dispersion of the fungus spores which will finally cover them.

(3) *Avoidance of spread by cattle, tools, etc.*—The writer's observations in various places in South Carolina during the past two years lead him to believe that cattle grazing in the fields spread the disease. They should not be allowed to pass freely from infected areas to healthy fields, and it would be better not to pasture such infected fields. Tools should be carefully cleaned after cultivating the diseased land. To insure complete destruction of the spores of the wilt fungus, such tools should be scoured clean and then washed with a 2 per cent solution of formalin or a 5 per cent carbolic acid solution.

(4) *Care of the compost heap.*—The fungus is sometimes introduced into the barnyard and compost heap, so that the manure becomes a source of general infection to healthy fields. The utmost care should be taken to keep diseased plants out of the manure, and if there are any indications that such plants have found their way into the manure, or if any new outbreaks of the disease are traced to the use of stable manure, all such manure and compost should be used on land where cotton will never be planted.

There is no objection to the use of stable manure which does not contain the spores of the cotton-wilt fungus, but experience has shown that in the case of the closely allied watermelon-wilt fungus a barnyard once infected will remain so for many years, and that all manure taken out of it will be likely to spread the disease. The same is probably true of the cotton-wilt fungus.

SELECTION OF RESISTANT RACES.

The most encouraging results have come from the endeavor of the Department to find a race of cotton which can be grown on the infected lands. There are always some plants in every field which resist the disease to a greater or less extent, and it frequently happens that of two plants in the same hill, equally exposed to infection, one will die and the other live to the end of the season. All degrees of resistance may be found, from plants nearly killed by the wilt disease to those entirely healthy. The latter are comparatively uncommon, however.

Different races of cotton vary considerably in their susceptibility to the wilt disease. This was shown by an experiment carried out by the Department on the farm of Mr. H. L. Galloway, at Dillon, S. C.

Twenty races, including the more prominent ones in cultivation, were planted in a field that was thoroughly infected with the wilt disease, and their comparative resistance determined in August by counting the number of plants remaining healthy, those partially diseased, and those killed.

None of the races tested were entirely resistant, but some showed great promise in this regard. The greatest resistance was shown by the Egyptian cottons, Mitafifi, Abbasi, and Jannovitch, which withstood the disease to a very marked extent. Very few plants were killed outright, although nearly all were considerably reduced in size and yield. The striking difference in resistance between these sorts and an ordinary upland cotton (King) is shown in Pl. II, fig. 1. The race figured here, the Jannovitch, was imported from Egypt by the Department through Messrs. Barbour Lathrop and D. G. Fairchild. It is a long-staple cotton of fine quality, said to be the result of a cross between the Egyptian and sea island cotton, and regarded as being adapted to upland culture. It has been widely distributed during the past year, and promises to be of great value. The other Egyptian sorts, Mitafifi and Abbasi, which were introduced at the same time as the Jannovitch, were also very resistant. They differed from that sort chiefly in the yield and the color of the lint. The most productive strain of Egyptian cotton grown on infected land was Mitafifi, No. 3992.

Sea island cotton, although closely related to the Egyptian, suffered very much. It was practically no more resistant than the upland cotton growing beside it. Nearly all the upland races proved very susceptible to the disease, though there were minor variations which must have been due to varietal differences.

One race only, the Jackson (Limbless), showed a marked resistance. In this respect it far surpassed all other upland cottons and nearly equaled the Egyptian. (See Pl. II, fig. 2.) The yield of this race on wilt-infected land was very good. Many plants were injured by the disease, but many others were exceptionally vigorous and there is no doubt that selection from these healthy plants would greatly increase the percentage of resistance. The relative resistance of these races in the experiment mentioned is shown in the following table:

Table showing varietal resistance of cottons to the wilt disease.

[The figures denote the comparative resistance of the different races on a scale of one thousand.]

Jannovitch	565	Brady	127
Mitafifi (average of 3 strains)	559	Cook's Long Staple	124
Abbasi	479	Excelsior	104
Jackson	453	Drake	90
Sea island	233	Jones	88
Eldorado	227	King	83
Texas Wood	162	Peterkin	71
Doughty	148	Truitt	71
Hawkins Prolific	142	Russell	55

It will be seen that some of the best kinds are among those most injured by this disease; but there were one or more plants in each race that entirely withstood the disease, and the seed from these has been saved with the intention of securing valuable resistant strains by cross-breeding them.

The ability of certain cotton plants to grow on infected land is due to the fact that the wilt fungus is unable to enter their principal root system and not to any lack of infection. This has been determined by microscopic examination. That infection of these plants has really taken place may be demonstrated by an examination of their roots for the little tufts of rootlets which mark the location of infections (see p. 8). The roots of plants taken from the row of Jannovitch cotton shown in Pl. II, fig. 1, were attacked by the fungus in over a hundred places, as found by actual count, yet in no case did the parasite penetrate as far as the main stem, while plants of King cotton in the adjoining row were completely overcome. A part of the root system of one of these resistant plants is represented in Pl. III, fig. 1. As determined by numerous microscopic examinations each little tuft of roots marks a point attacked by the fungus, so that there can be no doubt of the thoroughness of the infection and, furthermore, no doubt that such plants are actually resistant to the fungus.

It is evident that such an effect as the fungus has produced here must injure the plant considerably and this was found to be the case. The average height of plants grown on the infected land was 23 inches, while plants on adjoining land very slightly infected grew 42 inches high. Plate III, fig. 2, shows the difference between these plants. Such injury as this would of course greatly shorten the crop, but the indications are that seed selected from the most vigorous plants will be more resistant than the average. The best plants in our experimental plots on the infected land were nearly equal to those grown on healthy land and also showed a smaller number of root tufts.

In this connection the most important question is whether this quality of resistance to disease is transmissible through the seed to succeeding generations. An experiment designed to settle this point proved a remarkable success. It was carried out by Mr. Elias L. Rivers, of James Island, S. C., who selected a healthy plant of sea island cotton that grew in a badly blighted field in 1899. The seed from this resistant plant was saved and planted in a single row through a field that had been infected with the wilt disease for several years. The adjoining rows were planted with seed from his main crop, grown on noninfected land. The result is indicated in the photograph (Pl. IV) taken September, 1900. The wilt disease made almost a clean sweep through the ordinary cotton, 95 per cent of the plants being killed, while in the row planted with seed from the resistant plant *not a single plant was killed by the wilt disease.*

These plants were vigorous and productive. The dwarfing noted in

Egyptian and upland cotton grown by the writer on infected land at Dillon, S. C., was not so marked here. The quality of the lint was good, though not equal to the crop from which the selection was made. It is believed, however, that by continued cross breeding and selection in succeeding years the quality of the cotton may be improved without loss of resistance to the wilt disease. Work along this line has already been started in a small way by the Department, which it is hoped may be enlarged.

It has been shown that much can be accomplished in the control of the wilt disease of cotton by simply selecting seed from resistant plants. It is very probable that better results will be obtained by cross-breeding these resistant individuals, for in this way the resistant qualities of two plants will be combined and there will be added the increased vigor which usually comes from crossing. On the other hand, if the flowers of a resistant cotton plant should be fertilized by pollen brought by insects from a diseased plant, as may easily happen in the field, plants grown from the resulting seeds will very likely be less resistant than if they had been fertilized by pollen from another resistant plant. On this account, in the selection of resistant races, it will be desirable to cross by hand as many flowers as possible in order to increase the chances of success.

In connection with the work of the Department a large number of crosses between resistant plants have already been made. It has been our aim to secure resistant strains from our common races by cross-fertilizing plants of the same race, and at the same time to increase the productiveness and improve the quality by selecting the best plants of each sort for breeding.

The fact that the Egyptian cottons are resistant to the wilt disease has led to the attempt to produce a resistant long-staple upland cotton, by hybridizing resistant plants of the common upland races with the Egyptian cotton. It is very desirable that everyone who undertakes the breeding of resistant cotton should at the same time pay great attention to securing a more productive race and a finer quality of staple.

CONTROL OF OTHER WILT DISEASES BY SELECTION.

The indications are that other diseases similar to the cotton wilt may also be controlled by the selection of resistant races.

The wilt of the cowpea, which is a troublesome disease in many parts of the South, is caused by a fungus closely allied to that producing the cotton wilt (*Neocosmospora vasinfecta* var. *tracheiphila*). In this case we already have a race, known as Little Iron, which will grow on infected land. A fine crop of this pea was grown during the past season by Mr. T. S. Williams, of Monetta, S. C., on fields where the whole crop was lost last year and where other races planted alongside it this year have been practically ruined.

Further investigations will probably result in the discovery of other races of cowpeas which may be so improved by selection that they may be planted on land infected by the wilt disease.

The wilt disease of watermelons, also allied to the two preceding, may prove amenable to the same treatment. The Department has under way some experiments to determine the possibility of finding a race of watermelon which may be grown on infected land. This would be exceedingly desirable, for this disease has made the growing of melons for market impossible over large areas in the South which formerly produced them in great abundance.

CONCLUSIONS.

There is great promise of a successful remedy for the cotton-wilt disease in selection of seeds from healthy plants growing on infected soils and by continuing to select and cross-breed the most resistant plants in succeeding crops with a view both to resistance and quality of staple.

It would be well in the case of upland cotton to start with a race like the Jackson, which is already highly resistant, and improve and fix the quality by careful cross breeding and selection. In places where this cluster type of cotton is undesirable a resistant strain of the sorts commonly cultivated can probably be obtained by cross breeding and selection. It is hardly to be expected that this process will result in a perfectly immune race the first year. Even though much of the cotton become diseased, the selection should be continued each succeeding year until the quality of resistance is fixed.

In the case of the sea island cotton, where length and fine quality of staple are essential, the process of selection and breeding should be the same. Resistance to disease must be the primary requisite, and from the resistant plants those bearing the finest lint may be selected.

The Egyptian cottons will probably prove of the greatest value when crossed with our upland races so as to add the vigor and quality of the former to the productiveness of the latter. It is hoped that the Department will be able to extend its work along this promising line.

In addition to selection for resistance, all practicable preventive measures should be applied. Rotation of crops is even more important on these infected soils than on healthy ones, for the continual growing of cotton on these lands will increase the amount of disease and decrease the resistance of the cotton.

Prompt destruction of diseased plants is also very important. Every effort should be made to avoid the infection of healthy fields by animals, tools, wash water from diseased fields, diseased plants, infected compost, etc. As already stated, land once infected with this disease remains infected for an unknown period.

EXPLANATION OF PLATES.

PLATE I. Fig. 1.—A field of ordinary upland cotton at Dillon, S. C., showing the damage caused by the wilt disease (photographed in August, 1900). Fig. 2.—Field of healthy upland cotton adjoining the infected field shown in fig. 1 (photographed in August, 1900).

PLATE II. Comparative resistance to wilt disease of different races of cotton in experimental plots of Division of Vegetable Physiology and Pathology, on the farm of Mr. H. L. Galloway, at Dillon, S. C. (photographed August, 1900): Fig. 1.—Jannovitch, an Egyptian cotton, on the left, and King, a common upland race, on the right. Fig. 2.—Jackson, on the left, and Drake, on the right. These plots were planted at the same time and treated exactly alike.

PLATE III. Fig. 1.—Root tufts produced by partial infection of resistant plants. The roots figured here were from a plant of Jannovitch cotton taken from the row shown in Pl. II, fig. 1. There were about one hundred and fifty of these little tufts on this root. (Drawn by Mr. W. R. Scholl, from a root collected in September, 1900.) Fig. 2.—Egyptian cotton plants, showing the dwarfing effect of numerous partial infections of the small roots. The plant at the left came from noninfected soil and is healthy, while that at the right grew on infected land near by. (Drawn by Mr. W. R. Scholl, from a photograph.)

PLATE IV. Sea island cotton resistant to the wilt disease (photographed September, 1900, on the plantation of Mr. Elias L. Rivers, James Island, S. C.). The row in the foreground was planted with seed from a single healthy plant that grew in infected land the year before. The adjoining rows, now almost entirely killed by the wilt disease, were planted with seed of the ordinary, fine sea island cotton. There are a few scattered plants in these rows that have resisted the disease. It was from such a plant as these that the seeds planted in the middle row were taken.

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FIG. 1.—WILT DISEASE IN UPLAND COTTON DILLON, S. C.

FIG. 2.—HEALTHY FIELD OF UPLAND COTTON, DILLON, S. C.

FIG. 1.—JANNOVITCH, AN EGYPTIAN COTTON, ON THE LEFT; KING, AN UPLAND COTTON, ON THE RIGHT, SHOWING COMPARATIVE RESISTANCE TO THE WILT DISEASE.

FIG. 2.—JACKSON ON THE LEFT, DRAKE ON THE RIGHT, SHOWING COMPARATIVE RESISTANCE TO THE WILT DISEASE.

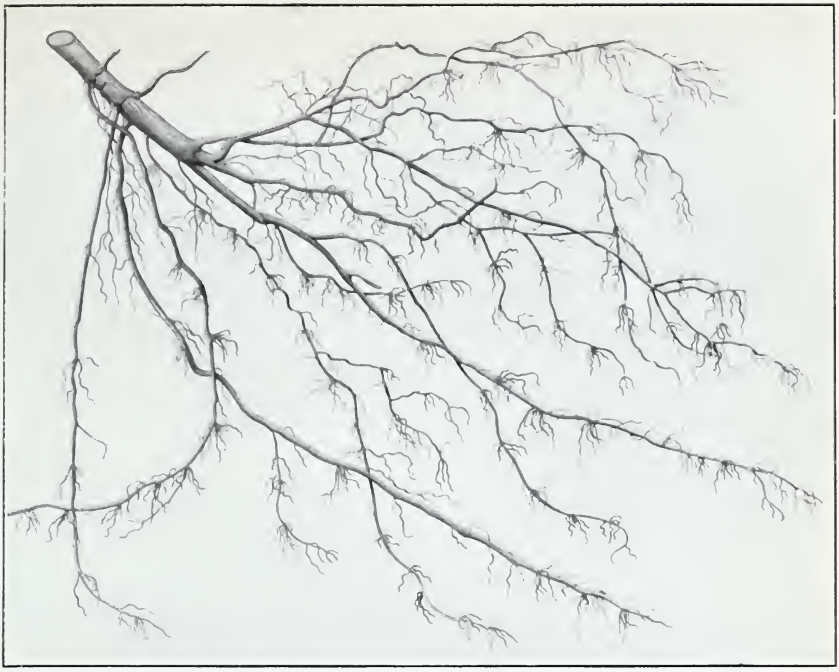

FIG. 1.—ROOT TUFTS PRODUCED ON JANNOVITCH COTTON BY REPEATED PARTIAL INFECTIONS BY THE WILT FUNGUS.

FIG. 2.—EGYPTIAN COTTON PLANTS FROM INFECTED AND NONINFECTED SOIL, SHOWING DWARFING EFFECT OF THE WILT FUNGUS.

SEA ISLAND COTTON RESISTANT TO THE WILT DISEASE. THE RESULT OF SELECTION FROM RESISTANT PLANTS.